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L. O. HOWARD, Entomologist.

THE LIME, SULPHUR, AND SALT WASH.

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USE AGAINST THE SAN JOSE SCALE IN THE EAST.

The experiences of the last two years with the use of the California, or lime, sulphur, and salt wash in the East have been in many cases of so satisfactory a nature as to cause numerous letters of inquiry, and indicate the need of a special circular of information. This wash is described and recommended in Circular 42 (second series) of this office, relating to treatment for the San Jose scale, and also in Farmers' Bulletin 127 on insecticides. But in these publications the information is very concisely given and none of the experiments on which are based the recommendations for the East are described. It is proposed in this circular to give a brief history of the employment of this wash in the East and to make such recommendations as the results justify.

EARLY TESTS IN MARYLAND.

With the discovery of the San Jose scale in Eastern nurseries and orchards the first thought naturally was to employ against it the washes which were very commonly used for its control in California and other Pacific coast regions. The results of the preliminary tests are recorded in the first general publication of this office on the San Jose scale, namely, Bulletin 3 (new series), pp. 57-71. Among many other tests made the lime, sulphur, and salt wash as used in California, and the Oregon wash, a slight variation of the latter, were the subject of careful experiments. This work was done by the writer, assisted by Mr. Coquillett, who while the California agent of this Division, had employed the lime, sulphur, and salt wash in many combinations and was thoroughly familiar with its use on the Pacific coast.

HOW THE WASHES WERE PREPARED.

The washes referred to were made after the following formulas:

California wash.—Lime, unslaked, 40 pounds; sulphur, 20 pounds; coarse salt, 15 pounds. Add 40 gallons of water to the above materials, stirring thoroughly while the lime is slaking. Boil fully three

hours, then add enough water to make 80 gallons of the solution. Strain through burlaps and apply milk warm, using only on deciduous trees and when the said trees are dormant. This formula is that given by Mr. H. B. Muscott, then chairman of the San Bernardino County Board of Horticultural Commissioners, who reported that the wash was prepared by a practical chemist employed by the commissioners and furnished at cost in concentrated form, and was extremely successful. A description furnished by H. P. Stabler, of Yuba City, Cal., of the method of making the California wash by means of a twelve-horsepower boiler and attached pipes and hot water tank was also given, an apparatus by means of which 300 gallons of the wash could be prepared at one time.

Oregon wash.—Sulphur, 15 pounds; slaked lime, 15 pounds; bluestone, $1\frac{1}{2}$ pounds; water to make 100 gallons. Prepared in the same way as the California wash. This mixture is interesting as representing a distinct variation in ingredients. It has little if any excess of lime, and the bluestone, which takes the place of the salt, probably does not add to the value as an insecticide and increases the difficulty of preparation. It is little employed.

RESULTS OF THESE TESTS.

The trial with these two washes was made November 17, 1894. They were used on peach and other fruit trees at the strength recommended in California and Oregon, and also at double this strength. The treated trees were carefully examined a month later, December 15, and only a very small percentage of the scales were found affected, not more than on untreated trees. The same results were seen with both strengths; in other words, the double strength was no more effective than the ordinary strength used on the Pacific coast. The trees were still whitened with the wash. These conditions had not changed at the time the orchard was given the general spraying with soap toward the end of April, 1895, which prevented following the action of these washes further.

INEFFECTIVENESS BELIEVED TO BE DUE TO CLIMATE.

The explanation which naturally suggested itself for the apparent failure of these Pacific coast washes to be effective in the East was in the difference in the climate between the two regions, and especially as earlier experiments (January–March, 1894) with the lime, sulphur, and salt wash conducted by the writer against the so-called West Indian peach scale (*Diaspis pentagona*) had shown similar unsatisfactory results.¹ In California these washes are applied in the dry season, and a long period may follow without rain. In the East a period more than

¹ Insect Life, Vol. III, pp. 118–119.

a few days without rain can not safely be counted on. So poor were the results, in fact, that the writer felt inclined to doubt the effectiveness of these washes even in California. But subsequent trips to California and careful investigation of conditions there, demonstrated to his complete satisfaction that the effectiveness of these washes on the Pacific coast had not been overstated.

CALIFORNIA WASH AGAIN TESTED.

The confirmation thus gained of the value of the California wash as an insecticide led the writer in the spring of 1900 to again institute some experiments with it against the San Jose scale and the Diaspis. These experiments are recorded in detail in Bulletin 30 (new series) of this Office, pp. 33-39. They include also parallel experiments with kerosene emulsified in the Bordeaux mixture and kerosene-lime emulsion, both suggested by Professor Galloway; and also a test with white-wash made at the suggestion of Doctor Howard. A special steam plant was prepared, so that the lime, sulphur, and salt wash could be made after the most approved methods and thoroughly boiled. An account of these experiments, so far as they apply to the lime, sulphur, and salt wash, is transcribed below from the publication cited. The report of the chemist on this mixture is of especial value and seems to confirm the view previously expressed on the relative effect of a moist and of a dry climate on the behavior of the wash.

RECORDS OF EXPERIMENTS IN 1900.¹

Lime, sulphur, and salt wash.—A mixture of this substance was prepared, differing slightly from the formula given in Farmers' Bulletin No. 19 in that the amount of lime was somewhat reduced, namely, from 40 to 30 pounds. This reduction in the amount of lime was made simply because in the ordinary formula the lime is very greatly in excess and remains as a pure lime sediment in the wash and has to be kept in suspension by agitation. Even as thus reduced there is still a considerable excess of lime. The formula followed was:

Lime	pounds..	30
Sulphur	do....	20
Salt	do....	15
Water	gallons..	60

The mixture was steam boiled all together in barrels about four hours and applied March 23 and repeated March 24. The hot liquid was taken immediately from the barrels at almost a boiling temperature and sprayed at once on the trees. A series of experiments was also made with the preparation of this wash on a smaller scale, following practically the same formula. The products obtained were submitted to the Chemist of this Department for analysis, and the assistant chemist charged with the work was especially advised just what features were supposed to be desirable and what points the analysis should bring out. The result of this analysis, made by Mr. J. K. Haywood, of the Bureau of Chem-

¹ Bul. 30 (new series), Div. of Entomology, pp. 34-37.

istry, as reported by Dr. H. W. Wiley, Chief Chemist, is given in a footnote.¹ It is very interesting and valuable as showing the probable exact chemical nature of the wash in a dry climate and correspondingly also in a wet climate, in these respects practically substantiating the theory which the writer had announced several years ago. The practical application of this wash, as described above, was made to pear and plum trees, both infested with the San Jose scale, the plum trees being very thickly covered with the scale from top to bottom and the pear trees scaly from the butts upward three or four feet, scattering more or less over the whole tree. The plum trees had also more or less of *Diaspis pentagona*.

The question naturally arose, in view of the extreme heat at which the liquid was applied, whether any results gained might not be due to the high temperature of the liquid rather than from any insecticidal action. To test this matter some plum and peach trees covered with *Diaspis pentagona* were sprayed on March 27 with water at boiling temperature, or nearly so, the nozzle being held within 3 or 4 inches of the bark and the spraying being very thoroughly done. At a distance of 18 inches, as tested by spraying one's hand, the mist or spray was barely warm; at a distance of 12 inches, fairly hot; and very hot at from 4 to 6 inches. The bark of the trees sprayed was cold to the hand as soon as spraying stopped. This hot-water spray, brought to bear closely on the scale insects, it was thought would kill them, although it would of course be impracticable to make such close-range application in general practice. On the contrary, however, the scales remained in a vigorous, healthy condition, and apparently did not suffer in the least from the warm douche.

The results, therefore, gained by the lime, sulphur, and salt wash may be properly ascribed, it is believed, to a true insecticidal value of the substance rather than to the temperature of the application. The trees treated with this wash remained nearly snow-white, little, if any, of the mixture being taken off by the light snow and rain of the 25th and 26th instant. Discoloration of the *Diaspis* began to be noticed on the 27th instant. On April 13 the *Diaspis* scale insects killed ranged between 20 and 50 per cent on the young, vigorous limbs. All were dead on the old trunk, where the wood was in a very unhealthy condition owing to the completeness of the infestation, both by the *Diaspis* and the *Aspidiotus*. The San Jose scale, so far as investigation could determine, seemed

¹ The lime, salt, and sulphur wash, as finally prepared, contains the following substances in solution: A large amount of (CaS) calcium sulphid, some of the higher sulphids of Ca (as CaS₃ and CaS₅), small amounts of (CaSO₄) calcium sulphate, and traces of (CaSO₃) calcium sulphite, and a large amount of (CaS₂O₃) calcium thiosulphate; also some of the excess of Ca(OH)₂ lime is in solution. The residue is composed of lime.

On evaporating down a portion of the wash, with blast and at a gentle heat, no decided change takes place. Calcium sulphid still remains, as does calcium thiosulphate. A small amount of sulphur is deposited (doubtless from the polysulphids of calcium), and the amount of calcium sulphate is increased to a small degree.

If such a wash were applied to trees in a dry climate, the various compounds formed would remain for a long time and only gradually decompose. Eventually, however, the calcium sulphid would decompose, most likely forming calcium sulphate and some hydrogen sulphid (H₂S), and the calcium thiosulphate would decompose, first setting free sulphur and calcium sulphite, which last would oxidize to calcium sulphate. The lime would change to calcium carbonate (CaCO₃) and the polysulphids would break down, yielding sulphur and calcium sulphid, which would in turn change as above.

In a wet climate the calcium sulphid and the calcium thiosulphate would soon leach out, leaving behind small amounts of calcium sulphate and a large amount of lime, which would in turn form insoluble calcium carbonate. In this latter case the tree would still remain white and appear to still have the wash upon it, but, in fact, very little other than the calcium carbonate would be left.

to be killed completely; no insects were found on the young, vigorous shoots or older wood. The trees were still whitened with the wash, which had not been carried off to any very great extent by the heavy rains of April 11 and 12. The infested trees, especially those that had been pruned back, made a very vigorous growth, and the fruiting and growth of the others were entirely satisfactory.

In this experiment, which differed so remarkably in results from other experiments made in the East with this substance, it must be noticed that the weather conditions were exceptionally favorable. The application was made on March 23, and no washing rains followed until April 11 or 12, the light rain and snow of the 25th and 26th of March being not enough to vitiate the wash particularly, as very little of the snow rested on the trees, and much that did gain lodgment fell or was blown off subsequently. A very light shower occurred on April 4, but the first heavy downpour and long rain occurred on the night of April 11.

This experiment would seem to indicate that if one could count on a week or two of good weather following an application, the lime, sulphur, and salt wash might be as beneficial in the East as on the Pacific coast. Its cost is inconsiderable compared with the other treatments for the San Jose scale.

During the summer of 1900 the writer spent considerable time in California and saw a great many deciduous orchards that had been treated with the lime, sulphur, and salt wash. This treatment had been made in the winter or early in the spring, before the trees had begun to leaf out, and at the end of August the trees were still distinctly whitened by the application, there having been no rains in the interim to remove it from the bark. Under such circumstances it is plainly to be seen that this wash has the maximum chance of effectiveness, and that it is thoroughly effective under these conditions, is beyond question. Its effectiveness is undoubtedly, in the first instance, chiefly due to the direct insecticidal action of the mixture; and possibly, secondarily, in protecting the tree by the limy and sulphurous coating, which remains for months and is undoubtedly distasteful to the young scales coming from old individuals which may have escaped, and perhaps retains enough of its insecticidal value to destroy many of them.

RECOMMENDATIONS BASED ON THESE EXPERIMENTS.

On the strength of these experiments the lime, sulphur, and salt wash has been since recommended by us, as already stated, as a remedy for San Jose scale in the East, with the understanding that unfavorable weather conditions, that is, heavy rains, immediately following treatment, may very probably decrease the benefits to be derived from it. That under favorable conditions its use may be thoroughly satisfactory, as much so as kerosene or crude petroleum, was fully demonstrated.

WORK DONE BY OTHER EXPERIMENTERS.

In the winter of 1901-02 Prof. S. A. Forbes instituted certain experiments with the California and Oregon washes, and his results of a highly satisfactory nature are given in Bulletins 71, 72, and 80 of the Illinois Agricultural Experiment Station. In brief, these seem to indicate that either the California wash or the Oregon wash, the preference in the later publications being given to the former, can be used under Eastern conditions with the probability of satisfactory results irrespective of weather conditions; in other words, Professor Forbes' experi-

ments were directed particularly to determine whether washing with rain or artificial washings of sprayed trees would affect the efficiency of the wash, and, rather surprisingly, such washings seemed to have had no prejudicial effect.

From the experience up to the present time it does not seem reasonable to assert from Professor Forbes' results alone that the California wash is not affected by hard washing rains, especially in view of the tests made by the Department Chemist, and the less favorable or contradictory results obtained by other experimenters, nevertheless the evidence is sufficient, on the whole, to warrant the placing of this wash among the best of the remedies in the East against the San Jose scale.

The work in Illinois has been supplemented by independent experiments in New Jersey, New York, Maryland, Georgia, and other States, and while all tests have not been successful, they seem to indicate that the lime, sulphur, and salt wash will, in the majority of instances, give decidedly good results, often destroying the scale nearly as effectively as an oil or a soap application.

HOW THE WASH AFFECTS THE SCALE INSECT.

The action of this wash on the scale is very slow and, judging from Professor Forbes' experience, it is possible that in the case of our preliminary work in Maryland in 1894, if the trees had been left for the summer without other treatment, the lime wash might have continued its effect and exterminated the scale in a much greater percentage than was the case in April. This wash coats the tree thoroughly, has a decided caustic insecticidal effect, and dissolves, to some extent, and loosens the scale covering, so that a large number of scales perish during the winter and early spring, and this action continues until the emerging of the first brood of young. As indicated above in the quotation from Bulletin 30, the weakened wash remaining on the trees through early summer may still be strong enough to kill some of the delicate larvæ and act as a deterrent to the settling of others until they perish. In fact, the chief benefit seems often to come at this season.

CAUTION IN ESTIMATING RESULTS.

It should be remembered that the sudden increase in the percentage of dead San Jose scales on trees in April may not necessarily be due to the wash, but rather to the fact that the male insects transform to the winged stage in April long before the females reach full growth, and hence there is an appearance of a sudden increase of dead scales, the abandoned scale covering of the male insect still adhering to the bark. This may often amount to 95 per cent of the scales. In the spring of 1902 the male scales in the Department orchard represented fully 95 to 98 per cent of the living insects on the trees in early April. The hatching of these, of course, gave an immediate appearance of an almost

complete extermination of the San Jose scale on these trees. This point is an important one and should not be overlooked in making estimates of the effectiveness of washes.

THE WASH AN AVAILABLE REMEDY FOR THE EAST.

The advantages of the California wash are notable. It is inexpensive, costing but little above one cent per gallon for materials, and does not entail any danger to the plant treated. Its disadvantages are the difficulty of preparation and heavy wear which it entails on apparatus, objections, however, which do not offset its advantages if future experience confirms the more recent results. The danger in careless hands in the use of petroleum oils, also their expense, and the great expense of soap washes, bring this lime, sulphur, and salt wash into especial prominence and recommend it to all who are so situated as to prepare it easily. This does not, however, discredit in the least the other washes mentioned.

COMPOSITION AND PREPARATION OF THE WASH.

The report of the Department Chemist (given in footnote on page 4) indicates sufficiently clearly the compounds entering into this wash and the behavior of these, respectively, in dry and moist climates. It is evident that in all the formulas, both those recommended above and others (practically every experimenter making a formula of his own), there is a great excess of lime which adds to the lime coating on the tree, and doubtless has its benefit as a deterrent. The composition of the wash is a matter of some indifference. I believe the formula followed in the experiments just described and recommended in Circular 42 is a good one to follow. This wash gave perfectly satisfactory results against the San Jose scale and is less wasteful in ingredients than many others, although still containing a considerable excess of lime, but perhaps not more than is desirable. The action of the salt is not very well known, and it is possible that this element could be eliminated, as indicated by some recent tests, without affecting the results of the treatment. Salt is, however, used in whitewash to give adhesiveness, and it may act in the same way in this wash, causing it to adhere longer and better than would be the case without it.

The wash is practically a sheep dip¹ imported into California, I believe, from Australia, and with the advent of the San Jose scale employed with little change against this insect, and by a lucky chance proving effective.

Prolonged and hard boiling increases the percentage of the higher sulphids, although in the main the liquid will consist of the simpler

¹For sheep dips recommended by the Bureau of Animal Industry of this Department, see Bulletin 21, B. A. I.

compounds of lime and sulphur; and from this fact it is to be inferred that these latter are by themselves effective, although a slight increase in efficiency may be gained by increasing the higher sulphids.

When making this wash in quantities of 50 gallons and upwards, it is necessary to boil for three to five hours, and especially at the start it should be stirred up thoroughly to prevent caking. In the process of making, the color changes from a yellow to the clear brown of sulphid of lime except for the excess of lime floating in it. It may be prepared by boiling in an ordinary vat of iron or, preferably, copper; or, is much more satisfactorily made by boiling in big hogsheads or barrels with steam. Where the wash can be prepared in the latter manner, its use is to be strongly recommended. It may then be made up at once with the full amount of water, and taken hot from the boiling tank and promptly applied so as to get the advantage of the higher sulphids and the full strength of the mixture. In transferring to the spray tank, pass it through an iron strainer. The spray tank must be provided with an effective agitator. The experiments of 1900, quoted above, discuss the matter of temperature fully. In important fruit districts it would be well worth while to adopt the plan followed very commonly in California—of organizing spraying companies to undertake at a reasonable charge the preparation of the wash and the spraying of orchards. In California the wash is furnished and put on the trees, everything included, at a charge of five cents per gallon.

PRECAUTIONS TO BE NOTED.

This wash is a winter application and can not be applied to trees in leaf. The best season is February or March. The fact that this wash is destructive to pumps and nozzles has already been indicated. The injury in this direction can be reduced to a minimum by carefully cleaning the pump each night with water. The Vermorel nozzle is the best one for the wash, and additional caps may be secured to replace worn ones. The use of an air pump instead of a liquid pump would save the wear of the lime on the pump; and doubtless our Eastern manufacturers could be induced to make a suitable apparatus of this sort. In spraying with this wash clothing is ruined, and only the oldest garments should be worn, and care should also be taken to protect the eyes to avoid unnecessary inflammation. There is, however, no special danger.

Approved:

JAMES WILSON,

Secretary of Agriculture.

WASHINGTON, D. C., *February 20, 1903.*



